

LASER STANDARD OPERATING PROCEDURE

Date Prepared: September 7, 2005
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___ New Request
X Modification

Issue Date: _____

Project: Polarized Source Qualification Estimated length of project: Indefinite

Description of Project: This LSOP describes laser system(s) used to qualify lasers and optical elements for the nuclear physics program polarized electron guns and for photocathode research.

Laser Inventory				
	Laser	Laser Class (1-4)	Wavelength	Average Power
1	Diode	3b and 4	630-680 760-860	0.2 W max
2	Ti-Sapphire	4	750-900	3 W max
3	Nd:YVO4	4	532	11 W max

Location of Use
 ITS Laser Room

Building No.
 58

Room No.
 129C

APPROVALS

SIGNATURE

DATE

Laser System Supervisor
 Joseph Grames

Department/Group Head
 Matt Poelker

Laser Safety Officer
 Patty Hunt

Physics Division EH&S Officer for Physics Division Laser Systems

Section 1 – Introduction to LSOP

This Laser Standard Operating Procedure (LSOP) describes laser operation in the Injector Test Stand (ITS) Laser Room in the Test Lab, Building 58. Operation includes manipulation and measurement of laser beam properties (polarization, spatial and temporal structure) necessary for the nuclear physics program polarized electron guns.

The Laser System Supervisor (LSS) for this LSOP is Joe Grames.

A copy of this LSOP is posted on the ITS Control Room Safety Board.

This LSOP includes:

- personnel requirements & list of authorized personnel
- laser specifications
- hazard description
- laser environment description
- specific procedures
- laser controls
- optical exposure calculations and nominal hazard zone
- schematics of the laser layout and interlock system

This LSOP addresses lasers of the type:

- diode laser systems
- modelocked Ti-Sapphire lasers
- frequency-doubled Nd:YVO4 green light pump lasers.

Section 2 – Laser Worker Approval Requirements

Laser Worker Requirements: A Laser Worker must have completed SAF156 “Laser Safety Training for the ITS Laser Room”. This means the Laser Worker has:

- a) been qualified by Jefferson Laboratory Occupational Health Physician as detailed in Section 6410 of the EH&S manual,
- b) taken a laser safety course administered by the safety officers at Jefferson Laboratory,
- c) read Section 6410 of the EH&S manual,
- d) read, understood, signed and dated this LSOP, and
- e) received walkthrough training with the LSS.

Accidental Eye Exposure: Accidental eye exposure to a laser beam requires immediate medical attention whether injury is apparent or not. If possible, the individual should remain and be transported in the upright position.

Clothing Requirements: Laser workers must not wear jewelry or clothing that presents a specular reflection hazard.

Spectator Protection Requirements: Laser Workers may escort Spectators in an interlocked laser area only after ensuring that the spectator is wearing appropriate safety eyewear. *Spectators must have received prior permission from the Laser System Supervisor before entering the interlocked laser area.*

Section 3 – Laser Specifications

A. Class 3b Diode Laser

Description: Jefferson Laboratory assembled low power diode laser system.

Type of Laser	semiconductor diode laser
Manufacturer	Various. Typical vendors include SDL, Polaroid, Hitachi, Mitsubishi, Sharp.
Model Numbers	Different for each vendor. The most frequently used diode laser is SDL-5401
Serial Numbers	Diode lasers are easily damaged and frequently replaced. Furthermore, vendors do not specify serial numbers on the diode laser housings because the housings are too small. For this reason, serial numbers are not recorded in this LSOP.
Wavelength range	630 nm to 680 nm (visible) 760 nm to 860 nm (infrared)
Power Range	Up to 200 mW, 50 mW typical.
Mode (i.e., time structure)	DC or pulsing at 499 MHz with 50 psec pulse width.
Beam Diameter (collimated, typical)	3mm
Divergence (uncollimated, typical)	10 degrees parallel, 30 degrees perpendicular to the laser junction.

Diode specific reference manuals and data are maintained in Bldg 90 room 118.

B. Class 4 Diode System

Description: This laser system consists of a Seed Laser (Class 3b) and a Diode Optical Amplifier (Class 4). Both are purchased from commercial vendors and mounted to a fabricated fixture. The two lasers operate together and therefore the system is described as a Class 4 laser.

Type of Laser	Semiconductor diode laser
Manufacturer	Seed lasers are described above. There are two vendors that provide Diode Optical Amplifiers; Spectra Diode Labs and Toptica
Model Numbers	Diode optical amplifiers; SDL-8630 and Toptica-8630
Serial Numbers	Diode lasers are easily damaged and frequently replaced. Furthermore, vendors do not specify serial numbers on the diode laser housings because the housings are too small. For this reason, serial numbers of seed lasers are not recorded in this LSOP.
Wavelength range	700 nm to 900 nm (infrared)

Power Range	Up to 200 mW
Mode (i.e., time structure)	DC or 499 MHz with 50 ps pulsewidth
Beam Diameter (collimated, typical)	3mm
Divergence (uncollimated, typical)	10 degrees parallel, 30 degrees perpendicular to the laser junction.

Diode specific reference manuals and data are maintained in Bldg 90 room 118.

Description of seed-amp operation: www.jlab.org/accel/inj_group/docs/2001/mopb012.ps.pdf

C. Class 4 Ti-Sapphire laser systems

Description: Ti-Sapphire lasers are higher power alternatives to diode lasers. Each Ti-Sapphire laser is pumped by frequency-doubled Nd:YVO4 green-light laser (Class 4) which in turn is pumped by high power diode laser bars (Class 4) embedded within the pump laser power supplies. The diode laser bars are not accessible and are therefore not described in this LSOP.

The Ti-Sapphire lasers used in the Laser Room are wavelength tunable and emit mode-locked pulses with pulse repetition rates at either 499 or 31 MHz. These lasers meet all ANSI/CDRH safety standards. Class 4 frequency-doubled Nd:YVO4 (green) pump lasers are contained within the Ti-Sapphire laser housing. A pump laser hazard exists when the Ti:Sapphire laser cover is removed for periodic alignment and maintenance.

Type of laser	Ti-Sapphire
Manufacturer	TimeBandwidth Inc
Model Number	Tiger
Serial Number	S/N 116,117
Wavelength Range	750 – 900 nm
Power	500 mW
Mode (i.e., time structure)	31.1875 MHz, 499 MHz, 70 ps pulsewidth
Beam Diameter	0.3 mm at output coupler
Beam Divergence	0.35 mrad +/- 10%

Type of laser	Frequency-doubled Nd:YVO4
Manufacturer	Jenoptik. This laser is contained within the Ti-Sapphire laser housing. Green light does not leave the Ti-Sapphire laser housing. Green light hazard only when the laser cover is removed.
Model Number	none
Serial Number	S/N 201,218
Wavelength Range	532 nm
Power	5 W
Mode (i.e., time structure)	DC
Beam Diameter	~ 5 mm at output coupler
Beam Divergence	0.35 mrad +/- 10%

Reference manuals for Ti-Sapphire lasers are maintained in Bldg 90 room 118

Section 4 – Hazards

Class 3b and Class 4 Diode Laser Systems

The diode laser system described in this LSOP emits visible and near-infrared light, which is hazardous to the retina and can cause blindness. Direct illumination of the eye must be avoided (i.e., do not look into the laser). The lasers can produce both specular and diffuse reflected beams that can be hazardous to the eye.

Laser light emitted directly from a diode laser is highly divergent. The application described in this LSOP (and virtually all other diode laser applications) requires that a collimating lens be placed very near the emitting aperture of the diode laser. In this way we obtain a collimated laser beam, approximately 3 mm in diameter. Without the collimating lens, the laser light is spread over a larger area and poses little hazard. Diode lasers require low voltage and use low current power supplies. Consequently, there are no high voltage hazards associated with these lasers. There are no user serviceable parts inside a diode laser and when damaged must be replaced.

Class 4 Ti-Sapphire Laser System

Ti-Sapphire lasers have similar wavelength and optical pulse structure to the diode lasers, however, they are more powerful than diode lasers. Ti-Sapphire lasers have no electrical connections and therefore pose no electrical or high voltage hazard. The light from the Ti-Sapphire laser can burn skin and eyes through direct illumination or specular reflection. Laser eyewear must be worn. The Ti:Sapphire laser is within a tooled housing with an interlocked top panel. The interlocked top panel may be bypassed for alignment and to access the internal Nd:YVO4 laser system. Commercial Ti-Sapphire lasers are housed in metal enclosures and are designed to meet all ANSI standards (e.g., labeled exit aperture, power supply with emission delay, keyed power supply, etc.).

Class 4 Nd:YVO4 Laser System

When the Ti:Sapphire laser housing is open, exposure to a commercial frequency-doubled Nd:YVO4 pump laser with wavelength 532 nm (green) is possible. This pump laser is powerful enough to burn skin and eyes through direct illumination or specular reflection. Laser eyewear for both the wavelength 532 nm and wavelengths 750 to 900 nm must be worn when performing maintenance on Ti-Sapphire lasers with the housing open.

The Nd:YVO4 laser hazard is minimized by maintaining a short distance between its output and the Ti-Sapphire lasers. The Nd:YVO4 laser is powered by 120V AC and therefore poses no high voltage hazard. There are no user serviceable parts within the Nd:YVO4 laser. We do not anticipate working on these lasers.

Section 5 – Laser Environment and Procedures

Laser Environment

The laser systems are located on one 4' x 8' optical table. The path of the laser beam should be maintained within the perimeter of the table and within a height of 8" above the table surface. Optical baffles 8" high are fixed along the perimeter of the laser table protecting personnel sitting on the side of the room with a desk work area. The baffles are painted with flat black paint to create a matte finish to minimize the hazard associated with diffuse laser reflections. Warning signs are posted and laser eyewear is available at the single entry door to the Laser Room. When the laser interlock is engaged the Laser Room entry door is magnetically locked and a yellow beacon illuminates at the entrance to the Laser Room. The door can then only be opened with a code known by Laser Workers.

Maintenance Procedure

Routine maintenance of the laser systems will consist of occasional realignment and optics cleaning. These procedures are described in the vendor manuals. Maintenance requiring replacement of parts should be carried out by vendor service representatives or qualified JLAB personnel. Laser eyewear should be routinely inspected for damage.

Alignment Procedures

The most hazardous time for the personnel occurs when laser alignment is taking place. Laser Workers must perform work in accordance with the standards set forth in *Appendix A – Alignment Guidelines*. Laser alignment is routine and includes (a) Pockels cell alignment to obtain circularly polarized light, (b) replacement of the Seed Laser or Optical Amplifier and (c) measuring the laser spot size. Only Laser Workers will perform laser alignment. Alignment procedures should rely on the use of diagnostics such as laser card viewers, photodiodes and power meters. Personnel should always wear laser eyewear when the laser interlock is engaged, unless the laser power is reduced to eye-safe levels (see Section 7).

Location of Laser Manuals

Laser manuals are stored in the Laser Room or in the Source Lab (Building 90, Room 118). Before undertaking laser alignment or servicing, the Laser Worker should consult the appropriate vendor laser manual.

Laser Exposure

Any eye exposure requires immediate medical attention. All exposure (eye or skin) must be reported to the LSS. Skin exposures should be reported to JLAB Medical Services. If possible, the individual should remain and be transported in the upright position.

Emergency Procedures

In case of fire leave the area immediately and pull the nearest fire alarm located at the Test Lab exit doors. A smoke detector within the Laser Room will disable the laser power supplies. Notify the LSS after mitigating the emergency.

Section 6 – Laser Controls and Laser Room Interlock

Laser Enclosure	Class 4 conditions exist in the Laser Room.
Laser Safety Eyewear	When exposure to laser light is possible green-colored eyewear (OD>2.72) are required for the Diode laser wavelengths 630-760 nm, green-colored eyewear (OD>4.01) for the Ti:Sapphire laser wavelengths 700-900 nm and orange-colored eyewear (OD>3.71) for Nd:YVO4 laser wavelength 532 nm.
Laser Interlock Switch	A laser interlock enable button is located at the laser interlock.
Laser Interlock Beacon	A yellow warning beacon illuminates outside the Laser Room door whenever the laser interlock is engaged.
10-Second Delay	Once the interlock is engaged greater than 10 seconds occur before the laser interlock shutter may be opened.
Smoke & Fire Detector	A smoke and fire detector exist to disable the laser in case of smoke or fire.

Laser Room Interlock Controls

The following occur when the Laser Room is interlocked:

- The Laser Room door is magnetically locked.
- The Laser Room entrance enclave beacon illuminates.
- Laser interlock shutters at the laser exit apertures may be opened after 10 seconds.
- The Diode laser system may be turned on with a 3 second delay.
- The Ti-Sapphire laser system may be turned on with a 10 second delay.

The following will break the interlock:

- Unauthorized entry breaks the interlock.
- Pressing the crash button in the Laser Room breaks the interlock.
- Pressing the crash button in the Laser Room entrance enclave breaks the interlock.
- An alarming smoke/fire detector located above the laser table breaks the interlock.

The following occur automatically when the interlock is broken:

- The Laser Room door magnetic lock is released.
- The interlocked indicator in the Laser Room turns off.
- The laser beacon in the Laser Room entrance enclave turns off.
- The laser interlock shutters at the laser exit apertures close.
- The Diode and Ti-Sapphire laser system controllers turn off.

Section 7 – MPE / NHZ calculations

MPE, OPTICAL DENSITY, AND NOMINAL HAZARD ZONE Calculations Injector Test Stand Laser Room - Room 129 C

Author: P. Hunt

The MPE, nominal hazard zone, and OD requirement for the eyewear are calculated according to the ANSI Standard for the Safe Use of Lasers A136.1 2000, using software package Lazan version 3.6 software supplied by Rockwell Laser Industries.

Laser parameters needed to calculate these values for the ITS Laser system:

Class 3b diodes

1. Diode laser at 0.630 microns and 200 mW average power, beam diameter 3 mm, beam divergence 0.20 mrad, 50 picosecond pulsewidth, repetition rate 499MHz.
2. Diode laser at 0.760 microns and 200 mW average power, beam diameter 3 mm, beam divergence 0.24 mrad, 50 picosecond pulsewidth, repetition rate 499 MHz,

Class 4 diode system

3. Diode laser at 0.700 microns and 200 mW average power, beam divergence 0.29 mrad, 50 picosecond pulsewidth, repetition rate 499 MHz.

Ti Sapphire lasers:

4. Tiger laser: 0.750 microns and 5 W power CW, beam diameter 3 mm, divergence of 0.35 mrad.
5. Part of Tiger Laser: enclosed Nd:YVO4

Assumptions:

- Beams always collimated.
- Beams are circular.
- CW beams: exposure 10 seconds for IR lasers, 0.25 seconds for visible lasers
- 7mm limiting aperture
- For diodes: information usually given for diodes includes the divergence for the uncollimated beam and the diameter of the collimated beam. The information that is required to calculate the nominal hazard zone is related to the worst case, or collimated beam. The equation used to determine the divergence of the collimated beam is: $1.27 * (\text{wavelength in microns})/(\text{beam waist diameter in mm})$

Results:

#	Laser (type)	MPE/eye (mW/cm ²)	NHZ (meters)	Required OD (eyewear)
1	Diode 630 nm	2.55	500	2.31
2	Diode 760 nm	1.32	479	2.60
3	Diode 700 nm	1	550	2.72
4	Ti:Sapphire 700-900 nm	1.26	2450	4.01
5	Enclosed Doubled Nd:YVO4	2.55	1430	3.71

March 12, 2004

Laser Hazard Analysis

Injector 3b diodes at 0.6300 μm

ANSI Z-136.1 (2000)

Location: Injector

Building: Tunnel

Reference: Injector

Rm:

Class: IIb

Mode: Multiple Pulse Shape: Circular	Average Power: Watts Exposure Time: Seconds	Beam Size on Diffuser: mm Diffuser-Observer Distance: Meters Viewing Angle off Normal: Degrees Reflection Coefficient: Percent
Major Axis Dimension: 3.00 mm Major Axis Divergence: 0.20 mrad	Pulse Energy: 4.01E-10 Joules Pulse Length: 5.00E-11 Seconds Pulse Rate: 4.99E+08 Hertz Pulse Time Envelope: 2.50E-01 Seconds	Fiber Optics Mode: None Min. Beam Waist: μm Numerical Aperture:
Minor Axis Dimension: mm Minor Axis Divergence: mrad	Lens Focal Length: mm Beam Size at Lens: mm	Small Source Range: Meters
Gaussian Criteria: e-1		

Maximum Permissible Exposure (MPE)		Small Source Intrabeam Viewing at Known Range	
Small Source MPE (Eye)	2.55E-03 W/cm ²	Beam Area	N/A
Extended Source MPE (Eye)	N/A	Calculated exposure	N/A
Small Area MPE (Skin) N/A for T<10E-9s	N/A	Minimum required optical density	N/A
Small Source Intrabeam Viewing		Nominal Hazard Zones	
Average power	2.00E-01 Watts	Small source diffuse reflections	N/A
Energy per pulse	N/A		
Pulse peak power	8.02E+00 Watts	Lens on laser condition	N/A
Time	2.50E-01 Seconds	Intrabeam exposure condition	5.00E+02 Meters
Limiting aperture (Eye)	7.00E+00 mm	Multi-mode fiber optics	N/A
Limiting aperture (Skin)	3.50E+00 mm	Single mode fiber optics	N/A
Irradiance at eye	5.20E-01 W/cm ²	Ocular Exposure to Diffuse Laser Radiation	
Radiant exposure at eye	N/A	Source type	N/A
Minimum required optical density	2.31	Actual viewing angle (alpha)	N/A
Filter transmittance	4.90E-03	Limiting viewing angle (alpha-min)	N/A
Small Source Diffuse Viewing		Maximum large source range	N/A
Average power	N/A	Required minimum optical density	N/A
Energy per pulse	N/A	Calculated exposure	N/A
Minimum range	N/A	Calculated Correction Factors	
	N/A	Thermal/photochemical factor: T1	N/A
Radiant exposure at eye	N/A	Near-infrared correction factor: CA	N/A
Power at eye	N/A	Visible wavelengths correction factor: CB	N/A
Energy at eye	N/A	Special near-infrared correction factor: CC	N/A
Minimum required optical density	N/A	Extended source correction factor: CE	N/A
Filter transmittance	N/A	Total pulses	1.25E+08
Small Source Multiple Pulse Factors		Extended source effective total pulses:	N/A
Small source effective total pulses:	1.39E+04	Multiple pulse correction factor: Cp (Extended)	N/A
Multiple Pulse Correction Factor: Cp	0.092	UV eye or skin exposure over 2 days	N/A
MPE rule applied:	Rule 2		

Comments

March 12, 2004

Laser Hazard Analysis

Diode at 0.7600 μm

ANSI Z-136.1 (2000)

Location: **Injector**

Building: **Tunnel**

Reference: **injector**

Rm:

Class: **IIIb**

Mode: Multiple Pulse Shape: Circular	Average Power: Exposure Time:	Watts Seconds	Beam Size on Diffuser: Diffuser-Observer Distance: Viewing Angle off Normal: Reflection Coefficient:	mm Meters Degrees Percent
Major Axis Dimension: 3.00 mm Major Axis Divergence: 0.29 mrad	Pulse Energy: 4.01E-10 Joules Pulse Length: 5.00E-11 Seconds Pulse Rate: 4.99E+08 Hertz Pulse Time Envelope: 1.00E+01 Seconds		Fiber Optics Mode: None Min. Beam Waist: μm Numerical Aperture:	
Minor Axis Dimension: mm Minor Axis Divergence: mrad	Lens Focal Length: mm Beam Size at Lens: mm		Small Source Range:	Meters
Gaussian Criteria: e-1				

Maximum Permissible Exposure (MPE)		Small Source Intrabeam Viewing at Known Range	
Small Source MPE (Eye)	1.32E-03 W/cm²	Beam Area	N/A
Extended Source MPE (Eye)	N/A	Calculated exposure	N/A
Small Area MPE (Skin) N/A for T<10E-9s	N/A	Minimum required optical density	N/A
Small Source Intrabeam Viewing		Nominal Hazard Zones	
Average power	2.00E-01 Watts	Small source diffuse reflections	N/A
Energy per pulse	N/A		
Pulse peak power	8.02E+00 Watts	Lens on laser condition	N/A
Time	1.00E+01 Seconds	Intrabeam exposure condition	4.79E+02 Meters
Limiting aperture (Eye)	7.00E+00 mm	Multi-mode fiber optics	N/A
Limiting aperture (Skin)	3.50E+00 mm	Single mode fiber optics	N/A
Irradiance at eye	5.20E-01 W/cm²	Ocular Exposure to Diffuse Laser Radiation	
Radiant exposure at eye	N/A	Source type	N/A
Minimum required optical density	2.60	Actual viewing angle (alpha)	N/A
Filter transmittance	2.54E-03	Limiting viewing angle (alpha-min)	N/A
Small Source Diffuse Viewing		Maximum large source range	N/A
Average power	N/A	Required minimum optical density	N/A
Energy per pulse	N/A	Calculated exposure	N/A
Minimum range	N/A	Calculated Correction Factors	
Radiant exposure at eye	N/A	Thermal/photochemical factor: T1	N/A
Power at eye	N/A	Near-infrared correction factor: CA	1.32
Energy at eye	N/A	Visible wavelengths correction factor: CB	N/A
Minimum required optical density	N/A	Special near-infrared correction factor: CC	N/A
Filter transmittance	N/A	Extended source correction factor: CE	N/A
Small Source Multiple Pulse Factors		Total pulses	4.99E+09
Small source effective total pulses:	5.56E+05	Extended source effective total pulses:	N/A
Multiple Pulse Correction Factor: Cp	0.037	Multiple pulse correction factor: Cp (Extended)	N/A
MPE rule applied:	Rule 2	UV eye or skin exposure over 2 days	N/A

Comments

March 12, 2004

Laser Hazard Analysis

Injector class 4 diodes at 0.7000 μm

ANSI Z-136.1 (2000)

Location: Injector

Building: Tunnel

Reference:

Rm:

Class: IIIb

Mode: Multiple Pulse Shape: Circular	Average Power: Exposure Time:	Watts Seconds	Beam Size on Diffuser: mm Diffuser-Observer Distance: Meters Viewing Angle off Normal: Degrees Reflection Coefficient: Percent
Major Axis Dimension: 3.00 mm Major Axis Divergence: 0.29 mrad	Pulse Energy: 4.01E-10 Joules Pulse Length: 5.00E-11 Seconds Pulse Rate: 4.99E+08 Hertz Pulse Time Envelope: 1.00E+01 Seconds		Fiber Optics Mode: None Min. Beam Waist: μm Numerical Aperture:
Minor Axis Dimension: mm Minor Axis Divergence: mrad	Lens Focal Length: mm Beam Size at Lens: mm		Small Source Range: Meters
Gaussian Criteria: e-1			

Maximum Permissible Exposure (MPE)		Small Source Intrabeam Viewing at Known Range	
Small Source MPE (Eye)	1.00E-03 W/cm ²	Beam Area	N/A
Extended Source MPE (Eye)	N/A	Calculated exposure	N/A
Small Area MPE (Skin) N/A for T<10E-9s	N/A	Minimum required optical density	N/A
Small Source Intrabeam Viewing		Nominal Hazard Zones	
Average power	2.00E-01 Watts	Small source diffuse reflections	N/A
Energy per pulse	N/A		
Pulse peak power	8.02E+00 Watts	Lens on laser condition	N/A
Time	1.00E+01 Seconds	Intrabeam exposure condition	5.50E+02 Meters
Limiting aperture (Eye)	7.00E+00 mm	Multi-mode fiber optics	N/A
Limiting aperture (Skin)	3.50E+00 mm	Single mode fiber optics	N/A
Irradiance at eye	5.20E-01 W/cm ²		
Radiant exposure at eye	N/A	Ocular Exposure to Diffuse Laser Radiation	
Minimum required optical density	2.72	Source type	N/A
Filter transmittance	1.92E-03	Actual viewing angle (alpha)	N/A
		Limiting viewing angle (alpha-min)	N/A
Small Source Diffuse Viewing		Maximum large source range	N/A
Average power	N/A	Required minimum optical density	N/A
Energy per pulse	N/A	Calculated exposure	N/A
Minimum range	N/A		
	N/A	Calculated Correction Factors	
Radiant exposure at eye	N/A	Thermal/photochemical factor: T1	N/A
Power at eye	N/A	Near-infrared correction factor: CA	N/A
Energy at eye	N/A	Visible wavelengths correction factor: CB	N/A
Minimum required optical density	N/A	Special near-infrared correction factor: CC	N/A
Filter transmittance	N/A	Extended source correction factor: CE	N/A
		Total pulses	4.99E+09
Small Source Multiple Pulse Factors		Extended source effective total pulses:	N/A
Small source effective total pulses:	5.56E+05	Multiple pulse correction factor: Cp (Extended)	N/A
Multiple Pulse Correction Factor: Cp	0.037	UV eye or skin exposure over 2 days	N/A
MPE rule applied:	Rule 2		

Comments

March 12, 2004

Laser Hazard Analysis

Tiger AN 116 at 0.7500 μm

ANSI Z-136.1 (2000)

Location: Injector
Building: Tunnel
Reference: Injector

Rm:
Class: IIIb

Mode: Multiple Pulse Shape: Circular	Average Power: Exposure Time:	Watts Seconds	Beam Size on Diffuser: Diffuser-Observer Distance: Viewing Angle off Normal: Reflection Coefficient:	mm Meters Degrees Percent
Major Axis Dimension: 3.00 mm Major Axis Divergence: 0.29 mrad	Pulse Energy: 1.00E-08 Joules Pulse Length: 7.00E-11 Seconds Pulse Rate: 4.99E+08 Hertz Pulse Time Envelope: 1.00E+01 Seconds		Fiber Optics Mode: None Min. Beam Waist: μm Numerical Aperture:	
Minor Axis Dimension: mm Minor Axis Divergence: mrad	Lens Focal Length: mm Beam Size at Lens: mm		Small Source Range:	Meters
Gaussian Criteria: e-1				

Maximum Permissible Exposure (MPE)

Small Source MPE (Eye)	1.26E-03 W/cm ²
Extended Source MPE (Eye)	N/A
Small Area MPE (Skin) N/A for T<10E-9s	N/A

Small Source Intrabeam Viewing

Average power	5.00E+00 Watts
Energy per pulse	N/A
Pulse peak power	1.43E+02 Watts
Time	1.00E+01 Seconds
Limiting aperture (Eye)	7.00E+00 mm
Limiting aperture (Skin)	3.50E+00 mm
Irradiance at eye	1.30E+01 W/cm ²
Radiant exposure at eye	N/A
Minimum required optical density	4.01
Filter transmittance	9.69E-05

Small Source Diffuse Viewing

Average power	N/A
Energy per pulse	N/A
Minimum range	N/A
Radiant exposure at eye	N/A
Power at eye	N/A
Energy at eye	N/A
Minimum required optical density	N/A
Filter transmittance	N/A

Small Source Multiple Pulse Factors

Small source effective total pulses:	5.56E+05
Multiple Pulse Correction Factor: Cp	0.037
MPE rule applied:	Rule 2

Small Source Intrabeam Viewing at Known Range

Beam Area	N/A
Calculated exposure	N/A
Minimum required optical density	N/A

Nominal Hazard Zones

Small source diffuse reflections	N/A
Lens on laser condition	N/A
Intrabeam exposure condition	2.45E+03 Meters
Multi-mode fiber optics	N/A
Single mode fiber optics	N/A

Ocular Exposure to Diffuse Laser Radiation

Source type	N/A
Actual viewing angle (alpha)	N/A
Limiting viewing angle (alpha-min)	N/A
Maximum large source range	N/A
Required minimum optical density	N/A
Calculated exposure	N/A

Calculated Correction Factors

Thermal/photochemical factor: T1	N/A
Near-infrared correction factor: CA	1.26
Visible wavelengths correction factor: CB	N/A
Special near-infrared correction factor: CC	N/A
Extended source correction factor: CE	N/A
Total pulses	4.99E+09
Extended source effective total pulses:	N/A
Multiple pulse correction factor: Cp (Extended)	N/A
UV eye or skin exposure over 2 days	N/A

Comments

March 12, 2004

Laser Hazard Analysis

Injector Frequency Doubled Nd: YVO4 at 0.5320 μm

ANSI Z-136.1 (2000)

Location:

Building:

Rm:

Reference: Injector, Enclosed Jentopik Class: IV

Mode: Continuous Wave Shape: Circular	Average Power: 5.00E+00 Watts Exposure Time: 2.50E-01 Seconds	Beam Size on Diffuser: mm Diffuser-Observer Distance: Meters Viewing Angle off Normal: Degrees Reflection Coefficient: Percent
Major Axis Dimension: 5.00 mm Major Axis Divergence: 0.35 mrad	Pulse Energy: Joules Pulse Length: Seconds Pulse Rate: Hertz Pulse Time Envelope: Seconds	Fiber Optics Mode: None Min. Beam Waist: μm Numerical Aperture:
Minor Axis Dimension: mm Minor Axis Divergence: mrad	Lens Focal Length: mm Beam Size at Lens: mm	Small Source Range: Meters
Gaussian Criteria: e-1		

Maximum Permissible Exposure (MPE)		Small Source Intrabeam Viewing at Known Range	
Small Source MPE (Eye)	2.55E-03 W/cm ²	Beam Area	N/A
Extended Source MPE (Eye)	N/A	Calculated exposure	N/A
Small Area MPE (Skin)	3.11E+00 W/cm ²	Minimum required optical density	N/A
Small Source Intrabeam Viewing		Nominal Hazard Zones	
Average power	5.00E+00 Watts	Small source diffuse reflections	N/A
Energy per pulse	N/A		
Pulse peak power	N/A	Lens on laser condition	N/A
Time	2.50E-01 Seconds	Intrabeam exposure condition	1.43E+03 Meters
Limiting aperture (Eye)	7.00E+00 mm	Multi-mode fiber optics	N/A
Limiting aperture (Skin)	3.50E+00 mm	Single mode fiber optics	N/A
Irradiance at eye	1.30E+01 W/cm ²	Ocular Exposure to Diffuse Laser Radiation	
Radiant exposure at eye	N/A	Source type	N/A
Minimum required optical density	3.71	Actual viewing angle (alpha)	N/A
Filter transmittance	1.96E-04	Limiting viewing angle (alpha-min)	N/A
Small Source Diffuse Viewing		Maximum large source range	N/A
Average power	N/A	Required minimum optical density	N/A
Energy per pulse	N/A	Calculated exposure	N/A
Minimum range	N/A	Calculated Correction Factors	
Radiant exposure at eye	N/A	Thermal/photochemical factor: T1	N/A
Power at eye	N/A	Near-infrared correction factor: CA	N/A
Energy at eye	N/A	Visible wavelengths correction factor: CB	43.65
Minimum required optical density	N/A	Special near-infrared correction factor: CC	N/A
Filter transmittance	N/A	Extended source correction factor: CE	N/A
Small Source Multiple Pulse Factors		Total pulses	N/A
Small source effective total pulses:	N/A	Extended source effective total pulses:	N/A
Multiple Pulse Correction Factor: Cp	N/A	Multiple pulse correction factor: Cp (Extended)	N/A
MPE rule applied:	N/A	UV eye or skin exposure over 2 days	N/A

Comments

Section 8 – Periodic Laser Room Safety Verification

(every 6 months or upon major re-configuration)

ITS Laser Room LSOP is posted in the ITS Control Room.

Permanent laser safety signs are posted.

Laser eyewear with proper OD/wavelengths are available.

Laser is enclosed in a tooled, interlocked housing under normal conditions.

Laser cannot be turned on without the laser control key.

Once the laser interlock is complete the door is magnetically locked and the entry code and exit button work properly.

Laser beacon illuminates the Laser Room when the interlock is engaged.

Laser emission indicator on laser controller illuminates when the laser is capable of producing laser light.

Interlock laser shutter reduce laser emission to a Class 1 by fully stopping the laser beam.

Laser shutter emission is delayed 10 seconds after laser interlock is engaged.

All crash buttons function to close the interlock laser shutter.

Laser interlock must be reset manually when the laser interlock is tripped.

Calibrated laser power meter available.

Smoke detector laser interlock functions.

LSS: _____

Date: _____

Section 9 – Authorized Laser Worker Personnel

Having read this document and completed the requirements in Section 2 the following personnel are authorized to use the ITS Laser Room laser systems:

JLab staff: authorized in the operation and maintenance of the laser systems.

<u>JLAB Staff</u>	<u>Signature/Date</u>
Joe Grames (LSS)	_____
John Hansknecht	_____
Matt Poelker	_____
Marcy Stutzman	_____
Josh Brittian	_____
_____	_____
_____	_____

Non-JLab: authorized in the operation of the laser systems, but not in the maintenance.

<u>Non- JLAB Staff</u>	<u>Signature/Date</u>
Lisa Kaufman	_____
Kent Paschke	_____
Ryan Synder	_____
Stephanie Bailey	_____
Riad Suleiman	_____
_____	_____
_____	_____

Section 10 – Laser Room and Optical Table Layout (typical)

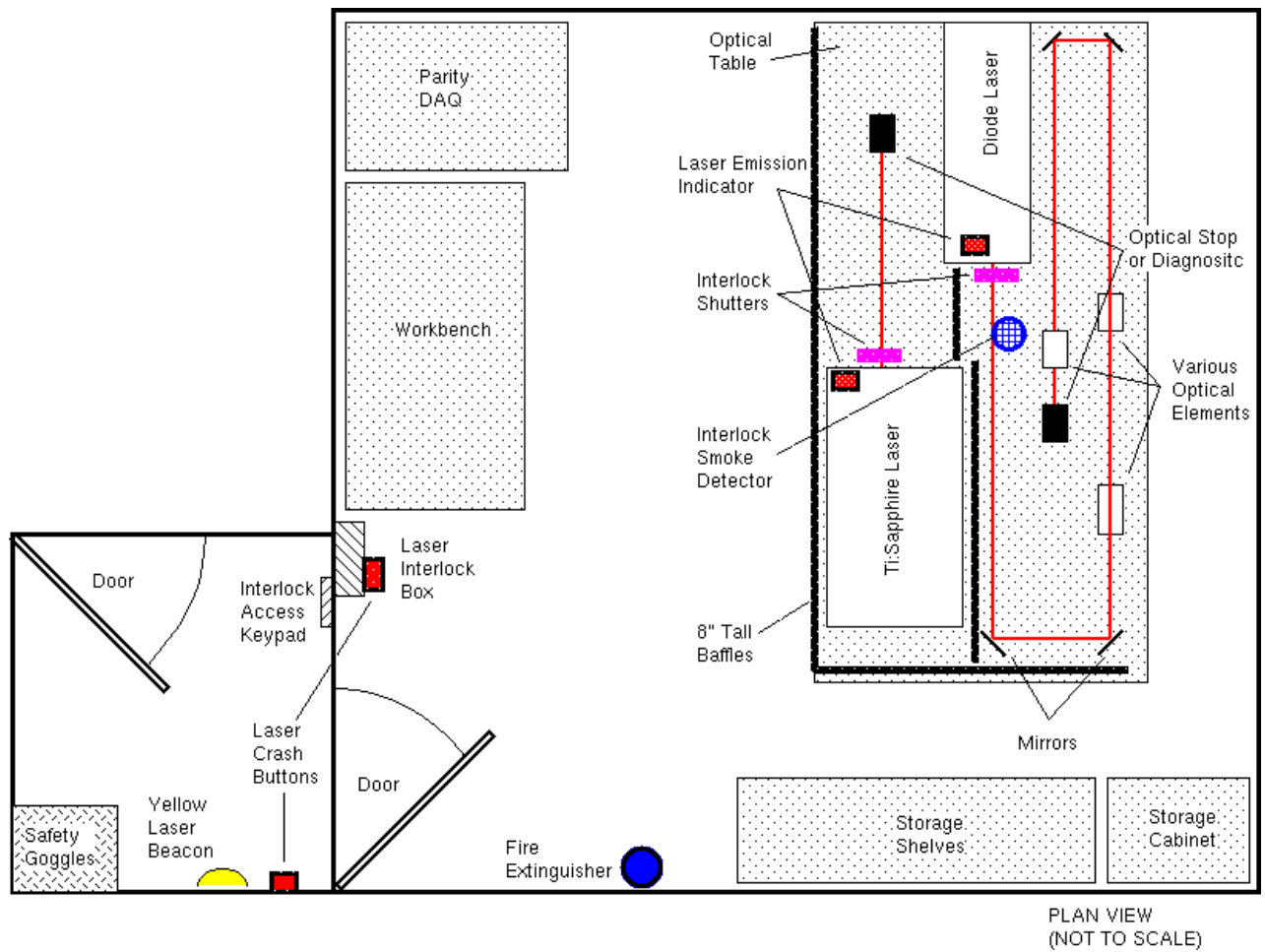


Figure 1. Laser Room and optical table layout (typical).

Section 11 – Interlock Schematic

1. The RED chain (crash buttons and smoke detector) must be made-up for remaining chains to be made-up.
2. Once the RED chain made-up, the Safety System Enable button will engage the GREEN Safety OK Relay chain.
3. With the GREEN chain made-up, the Enclave Laser Beacon MAGENTA chain is made-up.
4. With the GREEN chain made-up, the Diode & Ti-Sapphire Control keys enables the BLUE lasers chain.
5. With the GREEN chain made-up, the two Laser Shutters (A & B) BLACK chain are enabled.

(NOTE: The colors named are for distinction and do not imply any specific hazard type.)

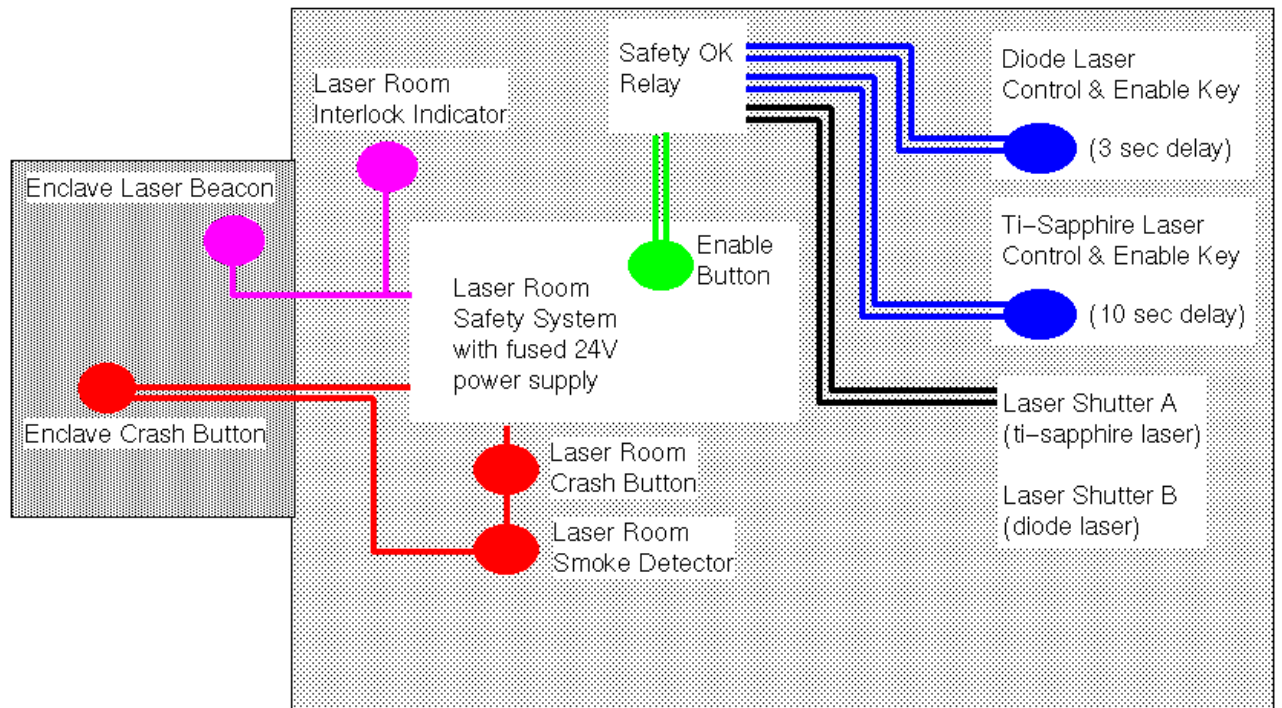


Figure 2. Interlock system schematic

Appendix A – Alignment Procedures

Techniques for laser alignment will be used to help prevent accidents during alignment. The requirements for alignment procedures for Class 2 laser systems and above, found in the EH&S chapter 6410 and ANSI Z136.1, do not apply to laser pointers, surveying equipment, barcode readers, hand held laser diagnostic equipment or similar general industry equipment.

Procedural Considerations

1. Watches, rings, dangling badges, necklaces, reflective jewelry are taken off before any alignment activities begin. Use of non-reflective tools should be considered.
2. Access to the room/area is limited to authorized personnel only.
3. Consider having someone present to help with the alignment.
4. All equipment and materials needed are present prior to beginning the alignment
5. All unnecessary equipment, tools, combustible material (if fire is a possibility) are removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the LSS
7. A NOTICE sign is posted at entrances when temporary laser control areas or unusual conditions warrant additional hazard information be available to personnel entering the area.

Alignment Methods to be used for this laser

1. There shall be no intentional intrabeam viewing with the eye.
2. Co-axial low power lasers should be used when practical for alignment of the primary beam.
3. Reduce the beam power through the use of ND filters, beam splitters and dumps, or reducing power at the power supply. Avoid the use of high-power during alignment.
4. Laser Protective Eyewear shall be worn at all times during alignment.
5. Skin protection should be worn on the face, hands and arms when aligning at UV wavelengths.
6. Beam Control- the beam is enclosed as much as practical, the shutter is closed as much as practical during course adjustments, optics/optics mounts are secured to the table as much as practical, beam stops are secured to the table or optics mounts.
7. Areas where the beam leaves the horizontal plane shall be labeled.
8. Any stray or unused beams are terminated.
9. Invisible beams are viewed with IR/UV cards, business cards or card stock, craft paper, viewers, 3x5 cards, thermal fax paper, Polaroid film or similar technique. Operators are aware that specular reflections off some of these devices is possible, and that they may smoke or burn.
10. Pulsed lasers are aligned by firing single pulses when practical.
11. No intra-beam viewing is allowed unless specifically evaluated and approved by the LSO/DLSO. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
12. Normal laser hazard controls shall be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.